U.S. Army Research Institute
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Research Report 1789

Simulating Night Vision Goggle Effects In a Virtual Environment: A Preliminary Evaluation

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U.S. Army Research Institute for the Behavioral and Social Sciences

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14. ABSTRACT *(Maximum 200 words)*:

This research examined the capabilities of virtual environments to simulate night vision goggle (NVG) effects. Different solutions for simulating NVG images were assessed. Two conditions simulated NVGs but used different software approaches. Two additional conditions simulated unaided night environments that required soldiers to wear NVGs. Four-man infantry teams conducted urban operation missions under each condition. Objective assessments were obtained on the number of events correctly detected and the average time required to detect an event. Subjective assessments of task difficulty and image fidelity were also made. No significant differences were found across night conditions for either event detection or time. Significant differences in task difficulty ratings occurred for movement, visual detection, and maintaining situation awareness. In general, tasks were more difficult to perform while wearing the NVGs compared to simulated versions of NVG images. Soldiers also ranked the conditions involving actual NVGs as more realistic. The unique contribution of virtual environments for night operations training may be at the entry level. However, specific image fidelity issues associated with the use of NVGs in simulated unaided night environments must be addressed if this approach is to be used as an effective training medium.

15. SUBJECT TERMS

Night vision goggles	PVS-7B	Night operations	Small unit leader training
Virtual environment	Urban operations	Dismounted infantry simulation	Individual combatant simulators

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Personnel Systems and Performance Technology

FOREWORD

This report describes selected aspects of the third year work effort under the Science and Technology Objective (STO) entitled *Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal*. The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Infantry Forces Research Unit performed this research in collaboration with the ARI Simulation Systems Research Unit, the U.S. Army Simulation, Training, and Instrumentation Command, and the U.S. Army Research Laboratory. The primary objective of the STO was to address selected technological and training issues related to high fidelity dismounted soldier simulation.

This report describes a preliminary research effort that examined the utility of virtual environments for night operations training. This research focused on the capabilities of virtual environments to simulate night vision goggle effects. The research was conducted at the Dismounted Battlespace Battle Lab (DBBL) Land Warrior Test Bed, Fort Benning, Georgia. The strengths and weaknesses of different software/hardware solutions for simulating realistic night vision goggle images in virtual environments were identified. The findings suggested that the unique contribution of virtual environments for night operations training may be at the entry level. These environments may offer a safe, effective setting for familiarizing the inexperienced soldier with the fundamental issues involving the use of night vision goggles. Critical aspects of the research were briefed to all key STO participants, including the Chief of the DBBL Simulation Center, at separate STO meetings on 7 February, 22 May, and 19 November 2001.

MICHAEL G. RUMSEY
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SIMULATING NIGHT VISION GOGGLE EFFECTS IN A VIRTUAL ENVIRONMENT: A PRELIMINARY EVALUATION

EXECUTIVE SUMMARY

Research Requirements:

Night operations are critical and very common within the military. Enhancing night proficiency is dependent to a large extent on soldier, leader and unit competency and confidence with various night technologies. Previous research identified a clear need for an entry-level training program in aided night vision. In theory, virtual environment technologies offer a potentially effective means for familiarizing soldiers with a number of specific aided night vision issues. The overall objective of this research was to evaluate the use of virtual environments for night operations training. Specific focus was directed to the night vision goggle (NVG) capabilities of the Soldier Visualization Station simulation system within urban environments.

Procedure:

Infantry teams each conducted four versions of a night movement to engagement mission in an immersive virtual urban environment. Scenarios were generally the same, differing only in starting location and sequencing of the appearance of civilians, enemy forces, vehicles, aircraft, and building structures. Each mission scenario was conducted under a different night condition. Two conditions simulated NVGs but used different software approaches to create their effects [NVG Sim A and NVG Sim B]. Two additional conditions simulated unaided night environments, but required soldiers to wear actual NVGs with the lens caps off (to approximate actual real world NVG images under good ambient illumination - Caps Off) or with the lens caps on (to approximate actual real world NVG images under poor illumination - Caps On). Simulated aiming lights were used in all conditions.

As teams moved through a virtual town, team leaders were required to report what they saw. All reports were recorded and time stamped. After each mission, soldiers rated the difficulty of performing specific tasks and activities. In addition, soldiers assessed the realistic aspects of each simulated night environment.

Findings:

Events were correctly detected from 53 to 63% of the time. However, there were no significant differences among conditions on the percent of events detected or time to detect the events. Task difficulty ratings did show significant differences across conditions. In general, executing tasks at night (detecting events, moving, and maintaining situation awareness) were perceived as significantly more difficult to perform in the Caps On condition than in the Caps Off condition. These tasks were significantly more difficult to perform while wearing NVGs than in either of the simulated NVG conditions where NVGs were not worn. The Caps Off condition was rated as the most realistic by soldiers. The NVG Sim A condition was rated as the

least realistic. The difference in these ratings reflected the higher image fidelity and enhanced realism created by wearing the NVGs. Not all night simulation conditions were acceptable. Soldier feedback indicated that the NVG Sim A condition was inferior to the other conditions on all major fidelity issues.

Utilization of Findings:

The results suggest that night simulations may offer a safe environment for preparing inexperienced soldiers in the fundamentals of how to use night vision goggles effectively. From a realism standpoint, NVGs should be worn in a simulated unaided night environment. By requiring the soldier to wear NVGs, he experiences first hand the restricted field of view and the importance of scanning. In addition, the soldier experiences the weight of the NVGs on the head/face area. In theory, these environments can also be used to show the effects of fluctuations in lighting conditions (e.g., shadows from full moon/stars, blooming effects from explosions, white light, muzzle flashes) on night vision as viewed from NVGs. However, specific image fidelity issues associated with the use of NVGs in unaided night environments must be addressed if this approach is to be used as an effective training medium.

SIMLULATING NIGHT VISION GOGGLE EFFECTS IN A VIRTUAL ENVIRONMENT: A PRELIMINARY EVALUATION

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Introduction

Night operations are critical and very common within the military. There is little doubt that the superiority of night forces at night is due in large part to its night technologies. But this night proficiency depends, to a significant degree, on soldier, leader, and unit competence and confidence, both with and without this equipment (Dyer, Pleban, Camp, Martin, Law, Osborn, & Galliard, 1999).

Dyer, et al. (1999) conducted extensive interviews with units, observer/controllers, and soldiers serving as the opposing force at the Joint Readiness Training Center. One key issue that surfaced from the interviews was the need for an entry-level training program in aided night vision. Before coming into units soldiers should be familiar with key night vision equipment such as night vision goggles (NVGs) and aiming lights. For example, soldiers must know how to adjust, focus, and maintain the goggles, and to troubleshoot problems. They must become accustomed to the weight and discomfort of wearing NVGs. Soldiers must also be aware of the limitations of goggles such as narrow field of view, loss of depth perception, limited help in zero ambient illumination, and the importance of proper scanning techniques.

Small unit leaders in particular require a basic understanding of goggle technology so they can project how they would appear to an adversary with goggles (e.g., the importance of moving in shadows or low ground to lessen the likelihood of being detected). They must also know how and when to use the NVG infrared aiming light.

Virtual environment (VE) technologies offer a safe means for familiarizing soldiers with the issues described above concerning NVGs and aiming lights. For example, VE technologies can be used to show the tunnel vision effect from wearing NVGs and how scanning can be used to counter (to some degree) this effect. Potentially, these technologies can be used to accurately depict to soldiers what various objects (people, vehicles, aircraft, buildings) look like under differing environmental conditions such as fog and smoke, and the impact of muzzle flash, headlights/spotlights, and explosions on images while looking through NVGs. Soldiers and small unit leaders (team, squad) can also develop a better feel for some of the difficulties involved in conducting tactical operations at night.

At the Dismounted Battlespace Battle Lab (DBBL) Land Warrior Test Bed (LWTB) at Fort Benning, Georgia, an individual soldier or small unit leader can directly experience the effects of varying night conditions such as fog, smoke or a moonless night, on vision and tactical performance in a virtual setting. In addition, limited NVG effects can also be simulated. Through the use of individual combatant simulators, soldiers can immerse themselves in virtual representations (data bases) of actual training sites such as the McKenna site at Fort Benning, and conduct limited night missions (e.g., clear a building, conduct area reconnaissance). Virtual environments can be particularly valuable for the soldier who has had little experience in night operations. Basic fundamentals required to operate effectively at night can be introduced and

demonstrated under relatively stress free conditions to maximize instructional effectiveness and enhance the limited time available for conducting real world night training exercises.

One of the best performing of the currently existing individual combatant simulation systems is a prototype version of the Soldier Visualization Station - SVS (see Salter, Eakin, & Knerr, 1999) developed by Reality by Design (RBD). This system represents the currently most viable overall technical approach for enabling soldiers to shoot, move, and communicate in virtual environments. In this system, the soldier stands in front of a large screen holding a rifle. The images depicted on the screen, including buildings, vehicles, and people are reasonably life-like in size and actions. The combination of images and action creates a very immersive (virtual) environment for the soldier.

The SVS is a PC (Pentium) based system with an inertial/acoustic tracker for simulated body position and weapon pointing. It includes a helmet-mounted display - HMD (helmet mounted monocular eyepiece linked to a camera on the rifle) that can be used to assist in aiming and looking around corners of buildings. The SVS has one flat screen on which images are presented by a rear projection device. Movement is accomplished by applying pressure to a weapon-mounted thumbstick. This allows the individual to move rather effortlessly throughout the virtual battlefield to include open terrain and urban environments.

Science and Technology Objective (STO) Virtual Environment Research

In 1998, the U. S. Army Research Institute (ARI) established a four-year Science and Technology Objective (STO) entitled Virtual Environments for Dismounted Soldier Simulation Training and Mission Rehearsal. The purpose of the STO is to examine selected technological and training issues that currently limit high fidelity dismounted simulation (see Pleban, Eakin, & Salter, 2000). A collaborative STO effort was established between the Infantry Forces and Simulation Systems Research Units of ARI, the U.S. Army Simulation, Training, and Instrumentation Command, and the Human Research and Engineering and Information Sciences and Technology Directorates of the U.S. Army Research Laboratory to address theses issues. The ARI portion of the STO is covered under the work package Virtual Environment Research for Infantry Training and Simulation (VERITAS). Key VERITAS work objectives include the following:

- Identify potential high-payoff tasks for small unit leader VE training
- Evaluate small unit training vignettes for use in infantry MOUT training
- Develop training strategies and performance measures
- Evaluate the training effectiveness of simulation systems
- Evaluate the use VE for night operations training

VERITAS Research

FY 99. FY 99 addressed the first two objectives (*Identify potential high-payoff tasks* and *Evaluate small unit training vignettes*) in separate investigations. Pleban et al. (2000) developed five small unit dismounted infantry scenarios based on the following tasks: 1) Assault, 2) Move Tactically, 3) Enter Building/Clear a Room, 4) Reconnoiter Area, and 5) React to Contact. Fire

team and squad level missions were conducted in a virtual urban environment setting modeled after the McKenna training area. A similar set of scenarios was run at the actual McKenna training site. Overall, the simulators were seen as effective for small unit training. Although the data were based on subjective reports, soldiers indicated that the simulations had improved their real-world performance on similar tasks conducted at the McKenna training site.

While the results were promising, the focus of this study was very basic, i.e., could soldiers perform key dismounted infantry tasks in a virtual environment. The results indicated that, for the most part, they could. Soldiers also listed a number of ways these simulators could be used effectively for small unit training. Potential training applications include:

- Training small team coordination/communication skills
- Mission rehearsal
- Developing and assessing alternative courses of action
- Developing and refining small unit leader decision-making skills

FY 00. FY 00 leveraged the findings from the previous research to address the next two VERITAS objectives (*Develop training strategies and performance measures* and *Evaluate training effectiveness of simulation systems*). The overall focus of this research effort (see Pleban, Eakin, Salter, & Matthews, 2001) was to investigate the potential of the SVS as a decision skills trainer. Seven experienced (platoon leader experience) and seven inexperienced (no platoon leader experience) officers role-played a dismounted infantry platoon leader and conducted, individually, four urban operation scenarios (missions) in a virtual environment setting. Scenarios included built-in decision points that required the officer to take specific actions at each point. Decision-making capability was assessed for each mission. In addition, soldier responses to the training and the simulation systems were obtained.

Objective decision-point accuracy improved significantly over missions. The officers' level of experience did not impact the rate of learning. Overall, the officers reported that their decision-making skills had improved as a result of the training they received and that decision-making skills could be taught effectively using virtual environment technologies. Virtual decision-skills training was viewed as particularly effective for the inexperienced lieutenant during the "walk" phase of training.

FY 01 research. The major research objective for FY 01 was to evaluate the use of virtual environments for night operations training. Specific focus was directed to the NVG capabilities of the SVS simulation system (the PVS-7B night vision goggle). Two simulated NVG software systems were evaluated. These systems were compared to actual PVS-7Bs that were worn by soldiers under simulated unaided night conditions (i.e., a night environment replicating approximate illumination levels seen by the naked eye at 0200). Previous testing showed that the images produced in the actual PVS-7Bs under these conditions were judged by experienced NVG users and military subject matter experts as very realistic. Evaluations emphasized the fidelity of the images and the overall experience created under each night condition.

Method

Overview

Four-man infantry teams conducted four versions of a night movement to engagement mission in an immersive virtual urban environment. Scenarios were generally the same, differing only in starting location and sequencing of the appearance of civilians, enemy forces, vehicles, and aircraft. Each mission scenario was conducted under a different night condition. Two conditions simulated NVGs (PVS-7Bs) but used different software approaches to create their effects (NVG Sim A and NVG Sim B). Two additional conditions simulated an unaided night environment where soldiers wore NVGs with the lens caps off (to approximate actual real world images under good illumination – Caps Off) or with the lens caps on (to approximate actual real world images under poor illumination – Caps On). [Note. The lens cap, which contains a pinhole at the center, restricts the amount of light that can pass through the NVGs. The primary function of the lens cap is to protect the image intensification tube]. Simulated aiming lights were used in all conditions. A retired non-commissioned officer, who role played the squad leader, offered minimal guidance during the scenarios and provided immediate feedback following the completion of each scenario during the after action reviews (AAR). ARI researchers served as additional observers and data collectors.

Participants

Participants were sixteen enlisted soldiers and non-commissioned officers from Fort Benning, Georgia. The average age of the soldiers was 25 years, 11 months. Average time in service was 75.2 months, with a range of 17 - 174 months. Nine soldiers were Airborne qualified and two had successfully completed Ranger school. Seven soldiers had completed the Primary Leader Development Course and four had completed the Basic Non-Commissioned Officer Course.

Soldiers had trained at the McKenna MOUT (Military Operations on Urban Terrain) site at Fort Benning an average of eight times since basic training (range 0 - 50 times). Only one soldier had operated a virtual individual combatant simulator such as the type employed at the LWTB. The majority of soldiers had some experience with military simulation systems. Four soldiers had trained using Simulation Networking (SIMNET) and/or the Close Combat Tactical Trainer.

All soldiers had previous experience with NVGs and aiming lights. The majority of soldiers had used NVGs (93%) and aiming lights (73%) when clearing buildings at night. Other equipment used by soldiers at night to clear buildings included: TAC lights - 60% (high intensity, white light illuminating device that attaches to weapon); chem lights - 73% (luminescent sticks); thermal sight - 40% (portable weapons sight for use in day or night conditions that can see through dust, smoke, haze and other battle field obscurants; and the PVS-4 weapon sight - 53% (portable image intensification device that amplifies reflected light such as moonlight, starlight, and sky glow).

Experimental Conditions

The two simulated NVG conditions, NVG Sim A and NVG Sim B, attempted to create images that the soldier would see if he was wearing a set of PVS-7Bs at night at the McKenna urban training site (green images with scintillation). However, for the software version of NVG Sim A used in this experiment, entities such as computer generated forces/civilians and vehicles were depicted in color (terrain and buildings were green) and there was no scintillation effects. NVG Sim B had scintillation effects. Both NVG Sim A and NVG Sim B provided unrestricted fields of view (FOV).

The Caps On and Caps Off conditions required that soldiers wear AN/PVS-7Bs. The soldiers used these NVGs while viewing a simulated unaided night portrayal of the McKenna training site. The resulting images were very realistic, i.e., appropriate shadings of green with scintillation and limited FOV. The Caps Off condition approximated images viewed under good illumination conditions. The Caps On condition approximated images viewed under poor illumination conditions. The images created in this condition were extremely dark and hard to see. The Caps Off and Caps On conditions served as the NVG real world baselines for good and poor illumination, respectively. For all conditions, weapon firing did not generate a muzzle flash.

Apparatus

AN/PVS-7B Night Vision Goggle. The AN/PVS-7B biocular night vision goggle is a lightweight image intensification, near infrared device that uses ambient light conditions. (See Figure 1). It amplifies reflected light such as moonlight, starlight, and sky glow so that the viewed scene becomes clearly visible to the operator. The sight does not emit visible or infrared light (except from the eyepiece) that can be detected by the enemy. It weighs 1.5 pounds and fastens via a harness to the soldier's head. An eyepiece diopter is provided so the device can be worn without corrective lenses. The AN/PVS-7B is equipped with an infrared light source and positive control switch that permits close-in viewing for map reading and close-up work in zero ambient light situations. (This feature was not used in this experiment.) An auto gain control insures the right level of illumination regardless of light sources in the FOV. Field of view is forty degrees with a focus range of six inches to infinity. Images are depicted in shades of green, ranging from light green to very dark as a result of the green phosphor element used in the goggle. These images are accompanied by a certain amount of scintillation (small specks in the viewing area). The AN/PVS-7B is powered by two AA batteries.

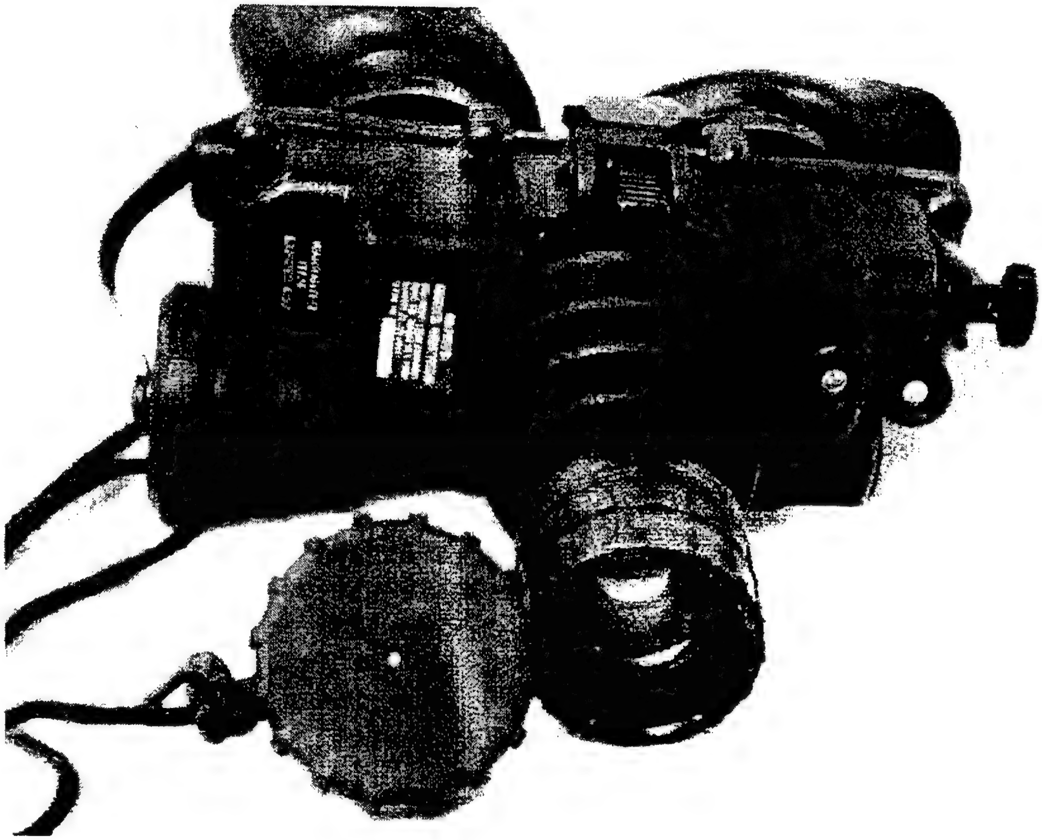

Figure 1. The AN/PVS-7B night vision goggle.

Soldier Visualization Station (SVS). Team members used the full-immersion SVS system with the exception of the HMD. The four immersive SVS systems were housed in their own enclosures. These enclosures were made of thick black cloth and fastened to a metal frame surrounding the SVSs. They were designed to dampen extraneous sound, reduce light, and minimize distractions from other people moving around the area.

The squad leader and the opposing forces (OPFOR) used the desktop versions. The desktop system was joystick controlled. The four stand-alone systems were linked to the desktops. Technical specifications of the two systems are shown in Table 1. Team members could communicate with each other and to both the team and squad leaders. However, team members were told that only the team leader was allowed to communicate with the squad leader. The squad leader and the simulation operator systems were adjacent to each other, but away from the SVS systems. The OPFOR systems were located in another room next to the SVSs.

ARI researchers observed events from either the simulation system operator's computer screen depicting a top-down view of McKenna or by looking at the squad leader's screen. For the squad leader and the OPFOR, images from the NVG Sim A and NVG Sim B Conditions were identical to what team members saw in their immersive SVSs except they were viewed on 17- inch computer monitors. However, in the Caps Off and Caps On conditions, the squad

leader and the OPFFOR saw the true unaided night depiction of images from the McKenna training site since they did not wear AN/PVS-7s.

Table 1
Technical Specifications of the Immersive SVS and Desktop SVS Simulation Systems

System Hardware (Immersive and Desktop)	• Pentium III – 450 MHz microprocessor • 128 Mb RAM • Obsidian 200 – 8440 3D Graphics Card • SoundBlaster AWE 64 Gold Audio Card • Removable 4.55 GB SCSI Hard Drive
Movement Control	• Weapon-mounted thumbswitch • Desktop SVS – Microsoft joystick control
Motion Capture/ Weapon Tracking	• InterSense Mark2 X-Bar Tracking System • Weapon tracking accurate to within ½ of 1°
Visual Display	• 90° x 60° FOV at center of enclosure (varies with position change) • Rear screen projection resolution 1024 x 768 • Desktop SVS resolution 800 x 600
Enclosures	• Aluminum frame over black sound-dampening fabric. (10 x 10 x 12)
Software	• Reality By Design proprietary software

Instruments

Biographical Information Questionnaire. The Biographical Information Questionnaire (Appendix A) is a multiple choice/short answer paper-and-pencil instrument designed to document the prior military training, experience, and vision status of each soldier, as well as their experience with computers and simulations.

Night Operations Capability Questionnaire. The Night Operations Capability Questionnaire (Appendix B) was completed prior to the experiment. This instrument focused on the soldiers' previous experiences in conducting night operations. Items were multiple choice or short answer and concentrated on such issues as the type of equipment used when clearing buildings at night, which team or squad members would have NVGs, white (TAC) lights, etc. In addition, soldiers rated how difficult it was to perform specific tasks or activities at night using NVGs and aiming lights related to movement, visual detection and identification, target acquisition, and maintaining awareness of team and enemy locations. Multiple choice items were based on a three-point scale with anchor points (1) *Could perform easily*, (2) *Could perform with difficulty*, and (3) *Could perform with extreme difficulty*. An additional response, (4) *Have not performed* was included for tasks/activities never performed by the soldier.

Virtual Environment Night Operations Capability Questionnaire. After each experimental condition, soldiers completed the Virtual Environment Night Operations Capability Questionnaire (Appendix C). Soldiers rated how difficult it was to perform specific tasks or

activities related to movement, visual detection and identification, target acquisition, and maintaining situational awareness. In addition, soldiers were asked to rate how quickly they could perform certain tasks in a virtual night environment compared to performing the same tasks in the real world at night using similar equipment, NVGs and aiming lights. Soldiers were also asked to list the most and least realistic features (both inside and outside buildings) of each simulated night environment condition and suggest modifications for enhancing the realism of each condition. The scaling format for the task difficulty items was identical to the one used for the Night Operations Capability Questionnaire.

Virtual Environment Night Operations Comparison Questionnaire. At the end of the experiment the Virtual Environment Night Operations Comparison Questionnaire was administered (Appendix D). Soldiers rank ordered the night conditions based on how well each environment simulated the experience of working under night conditions. Rankings could range from (1) *Very realistic simulation of night conditions* to (4) *Very poor simulation of night conditions*. In addition, the soldiers responded to open-ended questions that were presented orally in individual interviews by ARI researchers. Questions addressed the following issues:

- Rationale for ranking a particular night condition as the best (most realistic) or worst (least realistic).
- What aspects of the simulations were liked the most/least.
- Did wearing NVGs increase the realism of the simulation.
- How could virtual night environments be incorporated in training.

Virtual Environment Night Operation Experiment Spot Report Checklist. ARI researchers completed the Virtual Environment Night Operation Experiment Spot Report Checklist (Appendix E) during each mission. Mission start and end times were recorded. In addition, the checklist listed and ordered the appearance of various events in the scenario such as civilians standing in buildings, civilians moving across the street, burning vehicles-military (friendly/enemy), burning civilian vehicles (car, bus), dead civilians or soldiers, and enemy soldiers in buildings. Correct identifications made by soldiers were noted along with the time of identification during each scenario.

Night Scenarios

All scenarios were set as if in a small European town. The town was a virtual representation of the McKenna MOUT training site. A military subject matter expert developed four scenarios involving a movement to engagement mission. Scenarios involved eight to twelve events. Events represented all virtual images currently available on the SVS system to include civilians, friendly/enemy soldiers, civilian and military vehicles. Events also involved stationary as well as moving entities. These events were scripted to appear at differing times as the soldiers moved to their objective. All scenarios concluded with a firefight between the soldiers and opposing forces (OPFOR) that were played by live soldiers. Scenarios differed in the location from which the soldiers started each mission, the order of presentation of the various entities, and building location of the OPFOR.

Procedure

Pilot testing. Four individuals with NVG experience were recruited to take part in the pilot testing that lasted approximately one day. These individuals were briefed on the missions and then conducted one movement to engagement mission per night condition as a fire team. Any problems with a particular night condition or the NVGs were noted. All procedures including real time data collection using the spot report check lists were examined. The squad leader rehearsed his role with the other team members. Any modifications needed from a procedural standpoint were made.

Soldier training. Four soldiers arrived each morning at the Land Warrior Test Bed and were briefed on the objectives of the experiment. They were given a chance to ask any questions concerning their roles in the experiment. They then completed the Biographical Information Questionnaire.

After completing the questionnaire, soldiers were introduced to the SVS system and allowed hands-on time (approximately thirty minutes) to familiarize themselves with key system features (e.g., moving within the SVS area, moving via the thumb switch on the M4 rifle, engaging targets). In addition, they were shown what various entities looked like in the virtual world (e.g., buildings, furniture, friendly/enemy forces, civilians, vehicles, and aircraft) under simulated NVG conditions (NVG Sim B).

Experimental procedure. Following the training phase, soldiers met with the squad leader in the LWTB conference room. The squad leader briefed the mission to the team members who were given a chance to ask questions and then allowed 15-20 minutes to develop their plan. The squad leader emphasized that spot reports (to the squad leader) were required immediately following the detection of any event (e.g., civilian walking across the street, burning car).

Soldiers then proceeded to the simulator bay and to their assigned immersible SVS systems. The squad leader moved to a desktop system near the immersible SVSs. ARI researchers stayed with the squad leader. Each researcher had headphones and was able to hear all communication between the team and squad leaders. In addition, they could also observe the actions of the team from the screen of the squad leader's desktop SVS. The OPFOR were already in place in front of their desktop systems in a separate room. After completing system checks on the SVSs and the communication nets, the scenario started.

For each mission, the ARI researchers recorded all events identified by the team leader and the time that each event was called in using the spot report checklist. Presentation of the four night conditions was balanced using a Latin square design to control for possible learning effects. After each night condition/mission, the squad leader conducted a brief after action review. Soldiers then completed the Virtual Environment Night Operations Questionnaire.

This sequence was presented a total of four times. At the conclusion of the experiment soldiers completed the first part (rank ordering of night conditions) of the Virtual Environment Night Operations Comparison Questionnaire. Individual structured interviews were then conducted based on the remaining items from the questionnaire.

Results

Event Detection

Event detection was assessed from two perspectives. For each condition, the mean percentage of events correctly identified was calculated along with the average time taken to identify each event. Figure 2 shows the percentage of events correctly identified by condition. The detection rates were comparable across all four conditions, averaging approximately 60%. A one-way repeated measures analysis of variance (ANOVA) was computed which showed no significant differences for conditions, ($p > .05$). Descriptive statistics are provided by condition in Appendix F.

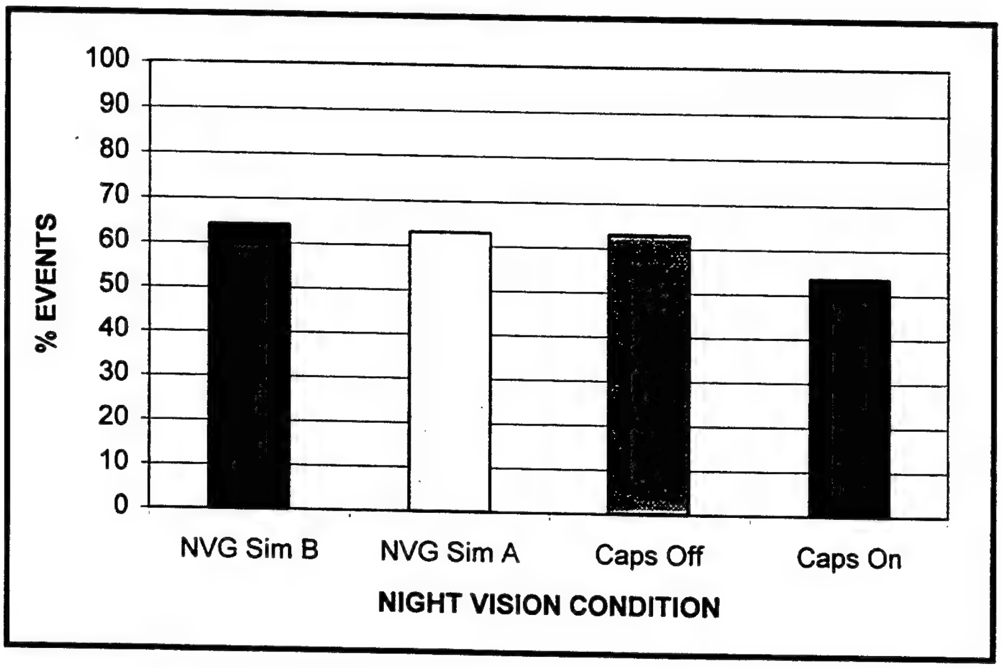

Figure 2. Percentage of events correctly identified by condition.

Figure 3 depicts the average time to identify an event by condition. Results from the one-way repeated measures ANOVA showed that differences among conditions were not statistically significant. This could be due, in part, to the large variation in response times observed in the Caps On condition (Mauchly's test of sphericity was not statistically significant. This indicated that the assumption of homogeneity of variance was not violated.) Descriptive statistics are provided by condition in Appendix F.

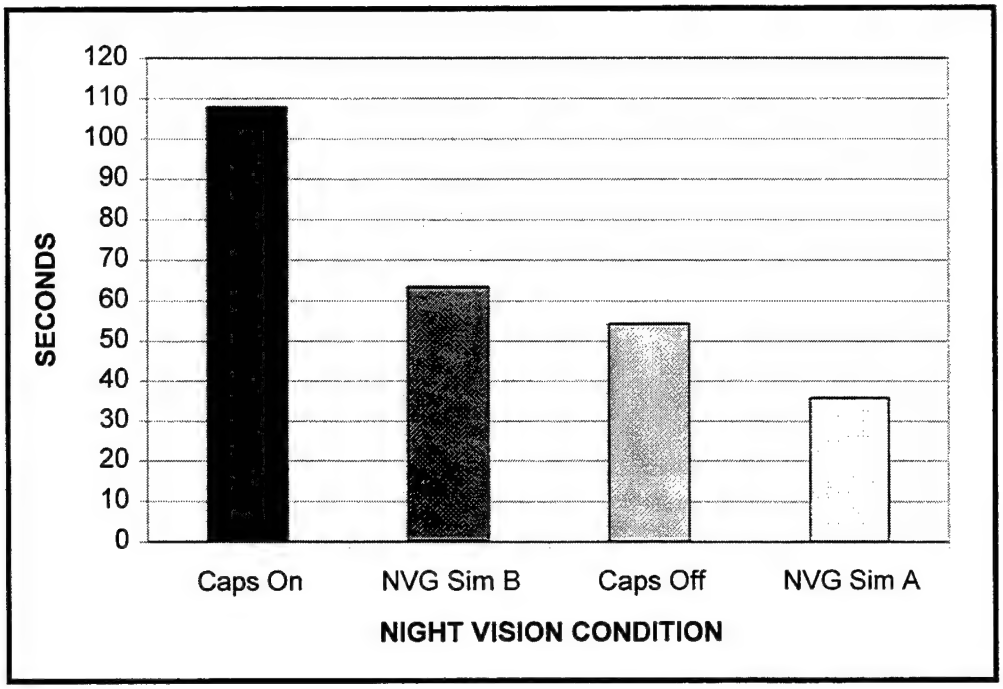

Figure 3. Average time to identify events by condition.

Task Difficulty Ratings

After completing each night condition, soldiers rated the difficulty of performing specific activities or tasks. A global mean difficulty rating was computed first, based on the fourteen items composing the four major task categories (movement, visual detection/identification, target acquisition, maintaining situation awareness). See Appendix C, Virtual Environment Night Operations Capability Questionnaire, for items in each task category. Results from the one-way repeated measures ANOVA were statistically significant, $\underline{F}(3, 42) = 20.41$, $\underline{p} < .001$. Figure 4 shows that tasks were most difficult to perform in the Caps On condition. Tasks were easiest to perform in the two simulated NVG conditions (NVG Sim A and NVG Sim B). Post-hoc comparisons (paired samples T-tests controlling for family wise error rate across tests; see Green, Salkind, & Axey, p. 216, 2000) showed only the NVG Sim A - NVG Sim B contrast failed to reach statistical significance, $p > .05$. See Appendix G for a complete listing of means and standard deviations by condition.

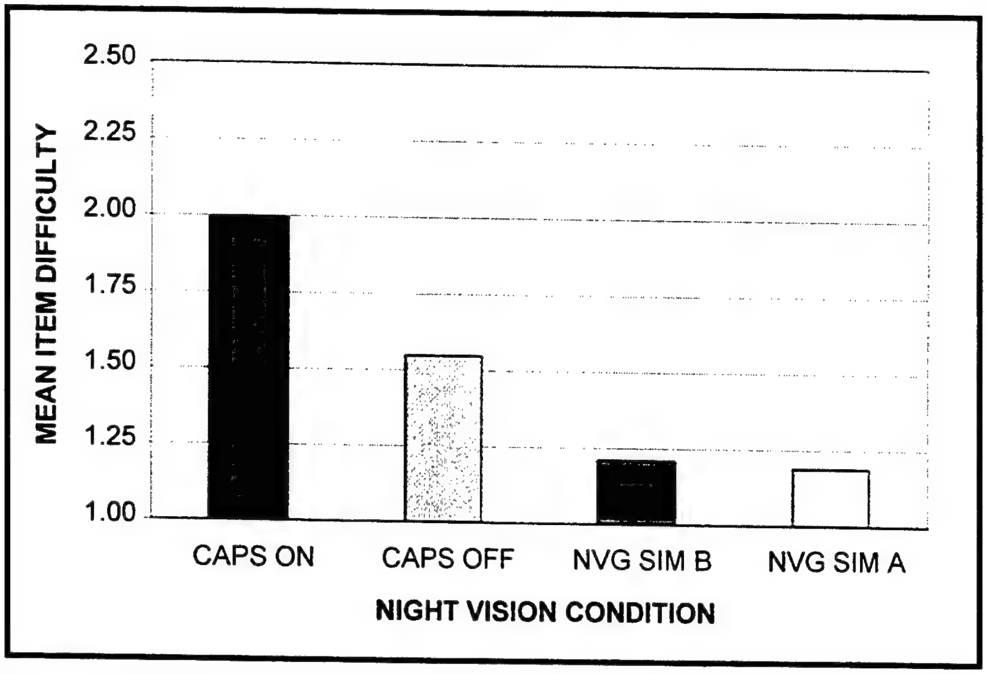

Figure 4. Difficulty ratings by condition collapsed over task categories.

Mean difficulty ratings for each task category were also computed (see Figure 5). Separate repeated measures ANOVAs were calculated for each category across conditions. The resulting ANOVAs for movement [$F(3,42) = 18.04$, $p < .001$], visual detection/identification [$F(3, 42) = 19.71$, $p < .001$], and maintaining situation awareness [$F(3, 42) = 19.68$, $p < .001$] were all statistically significant. The F value for target acquisition approached statistical significance, $p = .054$.

Post-hoc analyses for visual detection showed all pair-wise comparisons were statistically significant with the exception of the NVG Sim A-NVG Sim B contrast. For movement, the post-hoc comparisons showed that these tasks were rated significantly more difficult to perform in the Caps On than in the Caps Off condition. The analyses also showed that movement tasks in the Caps On condition were rated as significantly more difficult to perform than in either the NVG Sim A or NVG Sim B conditions. Similarly, these same tasks were rated significantly more difficult to perform in the Caps Off than in the NVG Sim B condition. Situational awareness tasks were also rated as significantly more difficult to perform in the Caps On than in the Caps Off conditions. These tasks were rated as (significantly) more difficult to perform in the Caps On than in either of the NVG Sim A or NVG Sim B conditions. Finally, situational awareness tasks were rated significantly more difficult to perform in the Caps Off condition than in the NVG Sim A condition. See Appendix G for a complete listing of means and standard deviations by condition and task category.

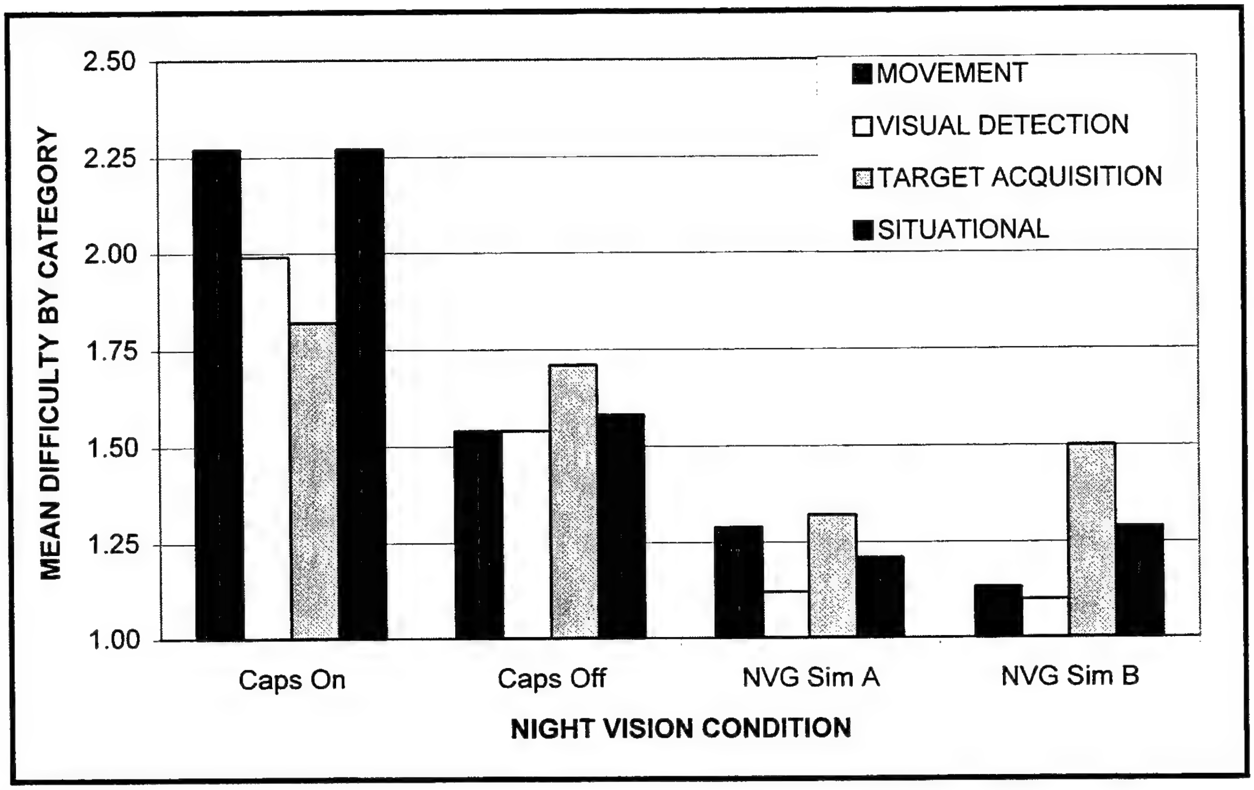

Figure 5. Difficulty ratings by condition and task category.

Real versus Virtual World Task Difficulty Comparisons

Prior to the start of the experiment soldiers rated the difficulty levels of the same tasks/activities contained in Appendix C (See Appendix B – Night Operations Capability Questionnaire) based on their real world experiences. Four one-way repeated measures ANOVAs were computed that included the soldiers' real world task difficulty ratings. A significant condition effect was obtained for movement [$F(4, 56) = 12.85$, $p < .001$], visual detection [$F(4,56) = 12.73$, $p < .001$], target acquisition [$F(4, 52) = 3.21$, $p < .05$], and situational awareness [$F(4,56 = 14.00$, $p < .001$]. Post-hoc analyses showed that real world task difficulty ratings did not differ significantly from soldier ratings in the Caps Off condition. However, tasks were rated significantly more difficult to perform in the Caps On condition than in the real world condition. For certain tasks such as movement and visual detection, analyses showed that tasks were, with one exception, significantly more difficult to perform in the real world than in the NVG Sim A and NVG Sim B conditions. See Appendix G for real world mean difficulty ratings and standard deviations by task category.

Realism of Simulated Night Environments

Most realistic features. After each night condition soldiers listed the most realistic features of each night environment. Soldiers' assessments addressed both the inside and outside of buildings. These responses are summarized in Tables 2 through 5.

Table 2
Most Realistic Features of the Caps Off Simulated Night Environment

Inside Buildings	• Good contrast between light and dark • Color, contrast, depth perception • Blurriness of images • Like looking through NVGs • Stairs, walls (darkness levels)
Outside Buildings	• Good contrast between light and dark • Depth perception • People, vehicles, glow and smoke from fire

Table 3
Most Realistic Features of the Caps On Simulated Night Environment

Inside Buildings	• Contrast • Light setting • Wearing the NVGs like the real thing • Hard to see. Dark • Size of rooms relative to personnel • Furniture
Outside Buildings	• View inside (buildings) • Light setting and perspective • FOV • Illumination • Wearing NVGs like the real thing • Trees • Movement

Table 4
Most Realistic Features of the NVG Sim B Simulated Night Environment

Inside Buildings	• Clearness of images • Depth perception • Walls, stairs, rooms, windows • Smoke, weapons, people • Easy to move and control • Cornering • Movement same or faster (as real world)
Outside Buildings	• Clear (images). Good light setting • Scintillation without NVGs • Terrain • Windows (able to see inside) • Differences in textures and lighting • Streets. Vehicles. People moving like real life. • Easy to move and control. Good speed.

Table 5
Most Realistic Features of the NVG Sim A Simulated Night Environment

Inside Buildings	• Movement • Rooms set up right • Furniture • OPFOR inside buildings
Outside Buildings	• Shooting into windows • Movement from place to place (slow) • People, tanks, buildings, vehicles

Soldiers' comments revealed some interesting patterns. For the Caps Off and Caps On conditions, the majority of comments focused on the fidelity of the images and the realism created by having to wear NVGs. Images, for the most part, were viewed as closely approximating the real world. Comments from the NVG Sim B condition focused on the general clarity of images produced by the simulation and the ability to move fairly smoothly inside and outside of buildings. Comments regarding the NVG Sim A condition focused on movement and the realistic aspects of the buildings, furniture, people, and vehicles. However, no mention was made concerning the realistic qualities of the images generated in this condition.

Least realistic features. After each night condition soldiers also listed the least realistic features of each night environment. Soldiers' assessments addressed both the inside and outside of buildings. These responses are summarized in Tables 6 through 9.

Table 6
Least Realistic Features of the Caps Off Simulated Night Environment

Inside Buildings	• Illumination too bright compared to outside walls • Hard to see • Difficulty moving around corners • Hard to move through stairwell (No explosive devices to counter OPFOR) • Small hallways • Limited sensing capability (no feel)
Outside Buildings	• Flat surfaced vehicles hard to see • Civilians walking around while taking fire • Bumbling movements • Peeking around corners • Hard to judge exactly when you hit a wall • Sight, sound, smell, no feel

Table 7
Least Realistic Features of the Caps On Simulated Night Environment

Inside Buildings	• Seeing the enemy • Light not bright enough looking through PVS-7Bs • No muzzle flash • Movement too chopped up. Too hard to control in small rooms • No furniture • Lack of senses
Outside Buildings	• Too blurry • No muzzle flash • No streetlights. Town should have been lit up more (from interior building lights) • Hard to move around (movement too choppy) • Lack of senses

A major theme voiced in both the Caps Off and Caps On conditions concerned the difficulty in moving, particularly inside buildings, moving around corners, or going up stairwells. In general, movement was viewed as too choppy or bumbling both inside and outside buildings. Images were very difficult to detect in the Caps On condition. Subjects' comments from the Caps On condition emphasized the importance of being able to see muzzle flashes (both enemy and friendly) and the absence of streetlights (which should have been present and would have added illumination).

Table 8
Least Realistic Features of the NVG Sim B Simulated Night Environment

Inside Buildings	• NVGS see too well • Images too bright and distinct • Poor light-dark contrast (from inside to outside buildings) • Unrestricted FOV • No muzzle flash (from friendly or enemy) • Communication too easy • Peeking around corners • Movement (Can only move at 90-degree angles. No side to side movement) • No weapon recoil • No furniture • Absence of most senses (key source of cues)
Outside Buildings	• NVGs could see too well • Images too bright and distinct • Hard too see enemy without muzzle flash • NVG unable to reflect changes in illumination from environment • Peeking around corners • Hard to turn (movement at 90 degree angles) • Easier to move outside than inside • Speed of movement too fast for night • Absence of most senses

For the NVG Sim B condition, the quality of images was a major theme. Soldiers reported that the simulated NVG images were too bright and distinct. They also noted the poor light-dark contrast from the inside to the outside of buildings and the inability of the simulated NVG to reflect changes in illumination from the environment. Movement was also mentioned. Problems identified included peeking around corners, moving only at 90-degree angles, the speed of movement (too fast for night), and the relative ease of movement outside versus inside buildings.

Table 9
Least Realistic Features of the NVG Sim A Simulated Night Environment

Inside Buildings	• Actual NVG nothing like this • Too bright • Too much illumination in contrast with outside • People were in color, too bright • No shadows • Everything was too easy to identify • No peripheral vision • Seeing through walls • Moving, maneuvering • Stairwell too chopped up • Limited weapon capabilities
Outside Buildings	• No change in illumination (in NVGs) to correspond to changes in environment) • No peripheral vision • Too bright • People were in color • Everything was too easy to identify • Could not see around trees • No shadows

The major theme addressed in the NVG Sim A condition concerned the fidelity of images produced in this environment. Soldiers reported that images were too bright, people were in color, and NVG images did not vary in accordance with changes in environmental illumination. As a result, people, objects, and vehicles were too easy to identify.

Did wearing NVGs (PVS-7Bs) increase the realism of the simulations? Eighty percent of the soldiers felt that wearing NVGs increased the realism of the simulations. Wearing NVGs reduced the FOV, which forced them to scan. Images were more realistic because soldiers were looking through the PVS-7. Finally, wearing the NVGs resulted in the same physical discomfort that soldiers would experience in the real world.

Overall realism. After completing all experimental conditions, soldiers rank ordered how well each condition was able to accurately simulate the experience of working under real world night conditions using NVGs and aiming lights. Forty percent of the soldiers ranked the Caps Off condition as the most realistic. The Caps On and NVG Sim B conditions were each ranked by twenty seven percent of the soldiers as most realistic. One soldier (six percent) ranked the NVG Sim A condition as most realistic.

Fifty-three percent of the soldiers ranked the NVG Sim A condition as the least realistic night environment. Forty-seven percent ranked the Caps On condition as the least realistic.

The explanations provided for the rankings by the soldiers were informative. There were two primary reasons why more soldiers ranked the Caps Off condition as the most realistic of the

four conditions. The first reason centered around image fidelity. In general, the soldiers felt that the images created were the most realistic. Images were slightly blurry. Light and color were acceptable. Distance vision effects were similar to using PVS-7s in the real world. The green color of the images was viewed, not surprisingly, as quite realistic.

The second reason soldiers rated this condition as most realistic was because they were also required to wear a set of PVS-7s. This reduced the soldiers' field of view (FOV) and forced them to scan. The weight of the PVS-7 on the head created the same uncomfortable pressure that many soldiers experience in the real world. Together, these qualities greatly enhanced the overall realism of this condition.

The NVG Sim A condition was viewed by soldiers as unrealistic for many reasons. Images were too bright and distinct. Distance vision was too good. The OPFOR, for example, could be spotted from too far away. The contrast between light and dark was insufficient. Particularly disturbing was that soldiers could see colors other than shades of green in the NVG Sim A condition. Finally, as was the case with the NVG Sim B condition, FOV was unrestricted. As a consequence, soldiers were not forced to scan. Scanning is critical if night vision goggles are to be used effectively in real world night conditions.

Soldiers were more favorable in their responses to the NVG Sim B condition. Images were reported as more realistic than the NVG Sim A condition (images were still too good). The biggest problem was the unrestricted FOV and the absence of any type of realistic night vision headgear.

The Caps On condition was also ranked low, but for different reasons. Comments made by soldiers revealed that the problem was not that images were unrealistic, but that everything was too dark. The extreme darkness made it very difficult to identify people and various objects. Many were puzzled why PVS-7s were worn during (simulated) night conditions with caps on. A few soldiers equated the images created under this condition to a no-illumination night. The purpose of this condition was, in fact, to simulate a very poorly illuminated night condition (why the caps were left on the lens) to contrast with the Caps Off condition.

Value of Virtual Night Simulations

Soldiers were asked what they liked most about the night simulations. Many of the comments focused on potential training applications. One application was specifically night related. A number of soldiers reported that these virtual night environments would be particularly valuable for new soldiers as a "train up" prior to going to the field. These virtual night environments could be used to show the effects of different lighting conditions (moon, stars, shadows, blooming effects from explosions, white light, muzzle flashes) on aided night vision.

The second training application was more general in nature. Soldiers reported that these virtual environments could be used effectively for building team communication and coordination skills and refining tactics. Both training applications could be done in a safe

environment, free from outside distracters (e.g., excessive heat, cold, humidity, insects, rain) that can slow the learning of new tasks or procedures.

Overall, the soldiers liked the graphics and laser sights. Graphics were seen by some as fairly realistic.

Soldiers were also asked what they disliked. Comments focused on system deficiencies. Some were specifically night related. The majority of remarks were more general in content. Specific night comments concerned the absence of muzzle flash from both friendly and enemy soldiers and the superior vision of the OPFOR. This was most likely a result of the system employed (SVS desk top versus the immersible SVS used by soldiers).

Soldiers found the thumbstick on the weapon very difficult to operate smoothly, particularly inside buildings. Moving down the street or outside buildings was fairly easy. However, stacking outside doors and moving around or into corners inside buildings was very awkward. All fine movements were difficult. Movement was regarded by some as too "jerky".

One soldier did not like the toggle (thumbstick) mechanism because it got in the way of the semi-auto/manual selector lever. This limited practice involving selector lever manipulation, which is a critical skill for close combat in urban operations. A number of soldiers felt that the weapon trajectory was not accurate. They also felt that the absence of recoil and trigger pull was not realistic.

Some comments focused on the lack of sensation. Several of the more experienced soldiers felt that the simulation systems should have more sensing capabilities like touch and smell.

Incorporating Virtual Night Environments in Training

Soldiers' comments concerning how they would incorporate virtual night operations in their training fell into four general categories. These categories are discussed in the following sections.

Teaching basic night fundamentals. Soldiers reported that these virtual night environments would provide good preparation for inexperienced soldiers prior to going to the field. The virtual night environment could be used to show how vision is limited at night (e.g., restricted FOV, distance vision) and then provide specific experiences showing how people/objects look under different levels of illumination. If NVGs are used, then soldiers can practice scanning techniques.

Unit training. Virtual night environments can also be used to train/maintain small unit communication skills, practice team movement, coordination, fire control, and target discrimination. These environments can also be used to develop/refine tactics and fine tune unit SOPs.

Leader training. Virtual night environments can also provide useful training to small unit leaders. These environments can be used to demonstrate specific problems involved in moving at night. Soldiers also reported that these environments could be used to develop decision-making skills and improve levels of situation awareness.

Realistic previews. Some soldiers indicated that virtual night environments could be used to provide realistic previews of towns and buildings that they were about to enter. Units could take a virtual tour of the town and orient themselves with the layout of specific buildings.

System Modifications

Post-experiment interview responses were analyzed for specific recommendations for improving the overall realism of virtual night environments. Key points addressed by the soldiers focused on movement and control, sensing, and night capabilities. Comments are summarized in Table 10.

Table 10
Suggested Modifications for Improving Dismounted Infantry Virtual Night Environments

Movement/ Control	• No toggle to move around (more responsive system) • Easier movement through buildings (in close quarters) • Improved side to side to movement • Ability to peer around corners and fire quickly • Ability to crawl into windows • Easier way for entering doors and window
Sensing	• Ability to look up • No seeing through walls • Incorporate other senses (touch, smell, other battlefield sounds?) • Realistic weapon (muzzle flash, recoil, trigger pull) • Include headset
Night Capabilities	• Adjustable illumination conditions • More illumination from moon and stars • Include dark areas, shadows • Improve realistic aspects of flames (enhanced illumination, flickering shadows) • Restrict FOV and enhance scintillation (use NVGs) • Curve screen (to add some peripheral vision) • Fine tune light and dark green of NVG image • Interiors of rooms should be darker • Allow for use of NVGs, aiming lights, TAC lights, thermal, and chem lights

Discussion

The major theme that emerged from this research was the importance of fidelity or realism of the virtual night environment. Realism was assessed from several different perspectives.

Objective Performance

Objective performance was assessed in terms of the percentage of events correctly detected by condition and the time required to identify each event. In terms of the actual percentage of events identified, the four conditions did not differ statistically. Each team was able to identify from 53-63 percent of the events that they were exposed to during each condition (e.g., civilians moving across the street, burning cars, dead soldiers).

The average times required to identify events were not significantly different, although there were large observable differences across conditions. As indicated earlier, the variability in response times was higher in the Caps On condition than in the other three conditions. This could be due to differences in experience among soldiers. One team of soldiers who had worked together in the field at night devised a very effective procedure for moving under extremely poor illumination conditions which involved using aiming lights to identify soldier and building locations (personal observation). This may have allowed these soldiers to get in position quicker than other teams to observe and identify the various events.

In summary, the analyses for both event accuracy and identification data indicated that performance in the NVG Sim A and NVG Sim B conditions were not statistically different from the two, more real world conditions, Caps Off and Caps On.

Task Difficulty Ratings

The task difficulty rating data showed more reliable patterns. For movement, visual detection/identification, and maintaining situation awareness, these tasks were perceived as significantly more difficult to perform in the Caps On than in the Caps Off conditions.

The Caps Off versus NVG Sim A and NVG Sim B comparisons were not as statistically reliable, but the pattern of ratings was consistent. Specifically, movement, visual detection/ identification and situation awareness tasks were rated as more difficult to perform in the Caps Off than in either the NVG Sim A or NVG Sim B conditions. In contrast, the Caps On versus NVG Sim A and NVG Sim B comparisons were all statistically significant and followed the same pattern as noted above in that tasks were more difficult to perform in the Caps On condition than in either the NVG Sim A or NVG Sim B conditions.

Interestingly, the difficulty ratings based on soldiers' previous real world experiences were not significantly different from task ratings provided in the Caps Off condition. This finding suggests that the use of NVGs in an unaided simulated night environment may have provided a reasonable approximation of NVG images as seen in the real world.

All tasks were rated as (significantly) more difficult to perform in the Caps On than in the real world. Clearly, wearing NVGs with the lens caps on created a poorly illuminated simulated night environment that few soldiers had ever experienced before.

The comparisons involving the real world ratings should be viewed cautiously. Soldiers were making assessments based on their own unique night experiences. How they weighted their past experiences in rating these tasks is impossible to determine. Ideally, a more accurate comparison would be if soldiers had gone out to the actual McKenna site, with PVS-7s, and were exposed to the exact same scenarios as used at the LWTB.

In summary, the pattern of results from the task difficulty ratings suggested that tasks performed in the simulated PVS-7 (NVG Sim A and NVG Sim B) conditions were easier to perform relative to the more realistic Caps Off condition. The Caps On condition simulated a realistic, but very dark night environment that made it extremely difficult to execute specific tasks when compared to the simulated PVS-7 and Caps Off conditions.

Subjective Comments

Most and least realistic features of simulated night environments. The subjective comments provided by soldiers were useful in identifying what made certain night conditions more realistic than other conditions. Soldiers' responses made it clear that image fidelity was the critical variable in determining their overall assessments of the realism provided by each condition. The Caps Off and Caps On conditions simulated the most realistic images in terms of contrast, color (correct shades of green), clarity (blurriness), depth perception, level of illumination, and FOV. The realistic images were the result, in large part, of soldiers wearing the AN/PVS-7B (which also produced the feel and discomfort associated with wearing the goggles).

Images produced in the NVG Sim B condition were too clear, which made it less realistic. Images were too bright and distinct and depth perception was too good. In addition, soldiers noted the lack of headgear and the unrestricted FOV. The NVG Sim A condition was clearly the least realistic in terms of image fidelity. Images were viewed as too bright, entities (people, vehicles) were in color, and the overall contrast between light and dark (too light inside relative to outside buildings) was poor.

Clearly, the Caps On and Caps Off conditions provided the most realistic night images. However, movement in these conditions was viewed as very unrealistic. This could be attributed to the increased difficulty in moving while wearing PVS-7s in combination with limited sensory cues provided by the SVS, and technical limitations associated with SVS system (i.e., using the thumbstick to move). Stacking movements, going up stairwells, moving inside rooms, and going around corners were very awkward. The awkwardness of these behaviors was exacerbated by having to wear the PVS-7s. However, precision, fine tuned movements have always been problematical with the SVS simulation system (Pleban et al., 2000).

Movement was also seen as unrealistic in the NVG Sim A and NVG Sim B conditions. Movements were too rigid (only 90 degree angles), too fast for night, or as in the Caps Off and Caps On conditions, too awkward inside buildings.

Based on the ratings and soldier comments, it is clear that the NVG simulations varied in their effectiveness. The NVG Sim A system, in particular, was viewed by virtually all soldiers as unacceptable in its present format.

Advantages and limitations of night simulations. When asked what they liked most about these night simulations, soldiers' responses focused on potential training applications (night relevant training and more general training uses). These will be discussed in a section on training below.

With regard to the negative aspects of the night simulations, soldiers did not like the absence of muzzle flashes from both friendly and enemy elements. This was a major problem for the Caps On condition which was extremely dark as well as for better illuminated conditions such as NVG Sim B. The presence of muzzle flashes would have provided valuable cues to soldiers trying to locate the direction of enemy fire. Sound localization is very poor in the SVS, so weapon fire, by itself, is not an effective cue for identifying enemy location (Pleban, et al., 2000). Follow up questioning with the technical staff at the LWTB indicated that this feature (muzzle flash) currently exists, but was turned off.

Another aspect of these night simulations that soldiers did not like was the unfair vision advantage of the OPFOR. This was particularly noticeable in the Caps On condition. Even though the OPFOR were forced to operate in the unaided night mode without PVS-7s (for the Caps On and Caps Off conditions) they still had several advantages. Although the OPFOR virtual environment was dark, it was not nearly as dark as the Caps On condition. The OPFOR also had an additional advantage in that they did not have to move. For the most part, the OPFOR stayed inside a building and waited for the soldiers to come to them. As soldiers approached the building, the OPFOR engaged them. The absence of muzzle flash made it difficult for the soldiers to detect where the firing was coming from. As a result, many casualties were taken before the soldiers were able to enter the buildings, at least initially. In retrospect, the scenarios, particularly the firefights, would have been more realistic if the OPFOR had also used the same immersive systems, to include wearing AN/PVS-7Bs, as the other soldiers.

Although not specifically night related, soldiers did not like the thumbstick used to move in the SVS system. As noted earlier, precise movements, particularly inside buildings, were difficult and viewed as very unrealistic. Stacking outside doors, moving around or into corners was very awkward. Soldiers operating the immersive SVS systems had a more difficult time in this respect compared to the OPFOR who used the SVS desk top systems. Movement on the desktop was accomplished with a joystick, which was easy to operate. Although the OPFOR did not move very much, their movements inside buildings were quick and efficient. While it is doubtful that the thumbstick will be replaced in the SVS system, improvements can still be made. For example, instead of using a stiff unmovable switch, one that could actually move forward, backward, left and right would provide more feedback to the user and let him better gauge his movements, particularly the precision movements required in small areas (see also Pleban, et al., 2001). Movement may also be improved by allocating additional training time to specific movement tasks or exercises.

A number of comments were directed to the lack of weapon realism (recoil, trigger pull) and accuracy. Accuracy issues could be due in part to poor bore setting prior to the start of the experiment. Weapon issues such as those described above, are not new (Pleban, Dyer, Salter, & Brown, 1998). Some improvements have been made, however, i. e., realistic loading of ammo magazines.

Incorporating virtual night environments in training. The most extensive use of these night simulations for training, from the soldiers' perspective, was to provide a safe environment for preparing inexperienced soldiers in night fundamentals. These virtual night environments could be used to show specific limitations in aided night vision such as restricted FOV (using NVGs) and distance vision. If actual NVGs are worn, then soldiers could use this time to practice different scanning techniques and become accustomed to the weight of the equipment around the head/face area. Ideally, these virtual night environments may also be used to show the effects of differing lighting conditions (e.g., shadows from full moon/stars, blooming effects from explosions, white light, muzzle flashes) on night vision when viewed from NVGs. At the present time, those illumination effects that can be simulated are not completely realistic (e.g., bright fire or night that produces no shadows). Some effects have never been demonstrated (e.g., blooming effects from different light sources) in a virtual environment. Clearly, soldiers saw the potential of these virtual environments. The question of how to realistically simulate a night environment with all the accompanying lighting effects poses a major challenge.

Other training applications for these virtual night environments mentioned by soldiers include small unit training (team movement/coordination, fire control, target acquisition, fine tune SOPs/tactics) leader training (decision-making, situation awareness), and realistic previews (layout of town). These applications were identified in earlier research (Pleban, et al., 2000).

System modifications for improving virtual environment night capabilities. Solutions for several of the desired night capabilities (night effects) could be addressed more cost effectively by requiring soldiers to wear NVGs. This would automatically restrict FOV, provide realistic scintillation, and force the soldiers to scan. In addition, use of NVGs would provide, for the most part, the appropriate contrast and color.

For some of the desired effects, solutions may present far more difficult challenges. For example, providing the capability to transition within a scenario from NVGs and aiming lights or thermal sights to TAC lights and bright interior lights and back to NVGs may not be feasible from a cost standpoint. However, adding shadows and darkening the inside of rooms is quite feasible.

A key capability is to depict the effects of different light conditions on aided night vision, as seen through NVGs. For example, blooming effects from looking at burning vehicles and the corresponding image degradation, and automatic gain adjustments were not observed while using NVGs in these scenarios. It is possible that the illumination levels created by this system were inadequate to trigger these effects in the NVGs. Software modifications may be able to address this problem by enhancing the brightness of explosions, fires, muzzle flashes, street lights, and TAC lights. (This would represent a far more cost effective solution than to attempt to simulate these effects entirely without the use of NVGs.) Depending on the availability of individual

combatant simulators and NVGs, the most feasible training might be to simply have soldiers wear NVGs in the barracks and the field and practice goggle adjustments, movement, and scanning techniques in a series of structured exercises that are practiced regularly.

Conclusion

This research suggested that the unique contribution of virtual environments for night operations training is at the entry level. These environments could be very useful for familiarizing inexperienced soldiers with the fundamental issues involving the use of NVGs. Incorporating NVGs in a virtual, unaided night setting, would provide a safe, relatively stress free environment in which soldiers could learn to use goggles (focus, troubleshoot) and experience first hand the unique characteristics of NVGs. However, certain software modifications are needed (to enhance the brightness of fires, muzzle flashes, etc.) to trigger the specific NVG images/effects. This would seem to represent the most cost effective way of enhancing the realism of these virtual environments for night operations training.

To insure that these individual combatant simulator systems are used to their greatest effectiveness, software developers must work closely with subject matter experts to identify the specific night vision effects or conditions that must be simulated and the optimal approach(es) for generating these effects. This can be accomplished by observing how infantry units operate at night and determining what equipment they use, how they use it, and wearing NVGs in field exercises (to develop a better understanding of the advantages and limitations of this technology). Developmental efforts should focus on this equipment and its effects on aided night vision. The end result of this process would be a virtual system that accurately represents the major characteristics of a NVG environment.

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Appendix A

Biographical Information Questionnaire

Name________________________ Unit________ Date________

Please fill in the blank or mark or circle the appropriate response.

1. What is your age? _____ Years _____Months

2. MOS _________

3. Rank ________

4. Time in service Years _____ Months _____

5. What is your current (or most recent) duty position? _______________
How long in this position? _______

6. What Army training courses have you completed? Check all that apply.

_____ PLDC _____BNCOC _____ANCOC ____ Airborne

_____BFV Leader Course _____ Ranger _____Air Assault

_____Other (please specify)______________________________

7. How susceptible to motion or car sickness do you feel you are?

1	2	3	4	5	6	7
not susceptible			moderately susceptible			highly susceptible

8. Do you have normal 20/20 vision **without glasses**? ____Yes ___No

9. Do you have 20/20 vision **with contact lenses or glasses**? ____Yes ____No ____NA

10. Are you color blind? _____Yes _____No

11. Are you _____right handed? _____left handed?

12. How many hours per week do you play 'virtual reality' type games? _____ hours per week

13. How often have you trained at the McKenna MOUT site (not including demos)? _____ times

14. Have you ever been in a Virtual Individual Combatant (VIC) simulator at the Land Warrior Test Bed before?

_____Yes _____No

If YES, which one(s)? (Describe if you cannot remember the name)

15. Have you had any <u>other</u> experience with military computer simulations?

_____Yes _____No

If yes, please describe briefly or give the names of the simulators.

Appendix B

Night Operations Capability Questionnaire

Name:____________________ Date:____________ Night Condition: **Real World**

1. When you clear a building at night, what equipment do you use?

_____TAC lights (white light)
_____Aiming lights
_____Chem lights
_____Thermal sight
_____NVGs
_____PVS-4 sight
_____Other (Please list)

2. Typically, what members of your team or squad would have NVGs?

3. Typically, what members of your team or squad would have TAC lights?

4. What do you do to counter the use of smoke in night operations?

5. What techniques do you use to mark or signal that a room is clear in night operations?

For the following questions, how difficult is it for you to perform the following tasks or activities at night in the **REAL WORLD. Use the following scale**:

1 = Easy to perform
2 = Difficult to perform
3 = Very difficult to perform
4 = Have not performed

Movement	**Using NVG (& Aiming Light)**	**Other equip. you use***
6. Move tactically through town.		
7. Move tactically inside buildings (to include stairs)		
8. Maintain position relative to other personnel.		

*List the equipment that you use to perform these tasks or activities at night.

6. ______________________________

7. ______________________________

8. ______________________________

Visual Detection/Identification	**Using NVG (& Aiming Light)**	**Other equip. you use***
9. Estimate distance to other personnel.		
10. Identify specific fire team members.		
11. Detect enemy soldiers.		
12. Detect civilians.		
13. Detect vehicles.		
14. Detect aircraft.		

*List the equipment that you use to perform these tasks or activities at night.

9. ______________________________

10. ______________________________

11. ______________________________

12. ______________________________

13. ______________________________

14. ______________________________

How difficult is it for you to perform the following tasks or activities at night in the **REAL WORLD. Use the following scale**:

1 = Easy to perform
2 = Difficult to perform
3 = Very difficult to perform
4 = Have not performed

Target Acquisition	**Using NVG (& Aiming Light)**	**Other equip. you use***
15. Aim your weapon.		
16. Detect enemy fire.		

*List the equipment that you use to perform these tasks or activities at night.

15. ______________________________

16. ______________________________

Maintain Situational Awareness	**Using NVG (& Aiming Light)**	**Other equip. you use***
17. Your location.		
18. Your fire team's location.		
19. The enemy location.		

*List the equipment that you use to perform these tasks or activities at night.

17. ______________________________

18. ______________________________

19. ______________________________

Appendix C

Virtual Environment Night Operations Capability Questionnaire

Name:____________________ Date:__________ Night Condition: ________

For questions 1-15, rate how difficult it was for you to perform the following tasks or activities at night in **this VIRTUAL ENVIRONMENT setting**. **Use the following scale**:

1 = Could perform easily
2 = Could perform with difficulty
3 = Could perform with great difficulty
4 = Did not perform

Movement	**Rating**
1. Move tactically through town.	
2. Move tactically inside buildings (to include stairs)	
3. Maintain position relative to other personnel.	

Visual Detection/Identification	**Rating**
4. Estimate distance to other personnel.	
5. Identify specific fire team members.	
7. Detect enemy soldiers.	
8. Detect civilians.	
9. Detect vehicles.	
10. Detect aircraft.	

Target Acquisition	**Rating**
11. Aim your weapon.	
12. Detect enemy fire.	

Maintain Situational Awareness	**Rating**
13. Your location.	
14. Your fire team's location.	
15. The enemy location.	

For items 16-19, check the response that best applies.

16. How quickly could you engage targets in this virtual night environment compared to the real world at night using similar equipment (NVGs and aiming lights)?

_____ Slower than the real world.
_____ About the same as in the real world
_____ Quicker than in the real world.

17. How quickly could you detect **stationary** people, objects, and targets in this virtual night environment compared to the real world at night using similar equipment (NVGs)?

_____ Slower than the real world.
_____ About the same as in the real world.
_____ Quicker than in the real world.

18. How quickly could you detect **moving** people, objects, and targets in this virtual night environment compared to the real world at night using similar equipment (NVGs)?

_____ Slower than the real world.
_____ About the same as in the real world.
_____ Quicker than in the real world.

19. How quickly could you move in this virtual night environment compared to the real world at night using similar equipment (NVGs)?

_____ Slower than the real world.
_____ About the same as in the real world.
_____ Quicker than in the real world.

20. What assumptions, if any, did you make concerning OPFOR night capabilities?

21. What were the <u>most realistic aspects or features</u> of this simulated night environment?

<u>Inside buildings</u>:

<u>Outside buildings</u>:

22. What were the <u>least realistic aspects or features</u> of this simulated night environment?

<u>Inside buildings</u>:

<u>Outside buildings</u>:

23. What <u>features, capabilities, etc.</u> would make this simulated night environment data base more realistic?

Appendix D

Virtual Environment Night Operations Comparison Questionnaire

Name:____________________ Date:__________ **VE Comparison**

1. Rank order the virtual night environments from 1-4, based on **how well** each was able to **accurately simulate** the experience of **working under night conditions**.
(Note. Use each number – 1, 2, 3, 4 only once in your rankings).

1 = **Best** (Very realistic simulation of night conditions)
4 = **Worst** (Very poor simulation of night conditions)

_____PVS-7 Good Illumination
_____PVS-7 Bad Illumination
_____RBD NVG
_____AS NVG

Structured Interview Questions

2. Why did you select the _____ system as the best?

3. Why did you select the_____ system as the worst?

4. What did you like most about these night simulations? Why?

5. What did you like least about these night simulations? Why?

6. Did wearing NVGs (PVS-7Bs) increase the realism of the simulation? If so, how?

7. How would you incorporate virtual night environments in your training?

Appendix E

Virtual Environment Night Operation Experiment
Spot Report Checklist

Date__________

Night Condition

Caps Off____ Caps On_____ NVG Sim A_____ NVG Sim B_____

Scenario Start Point

North_____ South_____ East__x___ West_____

Scenario Start Time_______ **Scenario End Time**_______

Event	Spot Report Made	Time
1. Civilian in building		
2. Civilian running across street		
3. Burning car & one dead civilian		
4. Burning tank/6 dead OPFOR/civ. run		
5. Rocket launcher		
6. Bus and one civilian		
7. Two OPFOR on 2nd floor		
8. One car and one civilian		
9. Unforecasted action		
10. Unforecasted action		
11. Unforecasted action		
12. Unforecasted action		

Comments.

Virtual Environment Night Operation Experiment
Spot Report Checklist

Date__________

Night Condition

Caps Off____ Caps On_____ NVG Sim A_____ NVG Sim B_____

Scenario Start Point

North__x___ South_____ East_____ West_____

Scenario Start Time_______ **Scenario End Time**______

Event	Spot Report Made	Time
1. Smoke		
2. Civilian in building		
3. 1 dead civilian/1 dead OPFOR/car		
4. Civilian walking across road		
5. Bus burning/dead civilian		
6. Civilian crossing street		
7. 1 dead civilian		
8. 1 burning car/1 car not burning		
9. OPFOR (1st floor)		
10. OPFOR (2nd floor)		
11. Helicopter		
12. Tank/BMP/6 dead OPFOR		
13. Unforecasted action		

Comments.

Virtual Environment Night Operation Experiment
Spot Report Checklist

Date__________

Night Condition

Caps Off____ Caps On_____ NVG Sim A_____ NVG Sim B_____

Scenario Start Point

North_____ South__x___ East_____ West_____

Scenario Start Time_______ **Scenario End Time**_______

Event	Spot Report Made	Time
1. Smoke		
2. Two burning tanks/6 dead OPFOR		
3. Civilian walking across street		
4. Civilian in tower (steeple)		
5. Burning car/dead civilian		
6. Two civilians moving across street		
7. Bus and 3 dead civilians		
8. OPFOR on 1st floor		
9. Burning tank/5 dead OPFOR		
10. OPFOR on second floor		
11. OPFOR squad moving at distance		
12. Unforecasted action		

Comments.

Virtual Environment Night Operation Experiment
Spot Report Checklist

Date__________

Night Condition

Caps Off____ Caps On_____ NVG Sim A_____ NVG Sim B_____

Scenario Start Point

North_____ South_____ East_____ West__x___

Scenario Start Time_______ **Scenario End Time**_______

Event	Spot Report Made	Time
1. Smoke/Tank/BMP/3 dead OPFOR		
2. Burning BMP		
3. Civilian moving east		
4. Burning Z SU Z3		
5. Burning bus		
6. Civilian moving east		
7. Burning car/2 dead OPFOR		
8. Two OPFOR (2nd floor)		
9. Unforecasted action		
10. Unforecasted action		
11. Unforecasted action		
12. Unforecasted action		

Comments.

Appendix F

Means and Standard Deviations for Percentage of Events Identified and Identification Times

Table F-1
Percentage of Events Correctly Identified by Condition

Caps Off	Caps On	NVG Sim A	NVG Sim B
M = 63.0	M = 53.5	M = 63.0	M = 64.2
SD = .13	SD = .16	SD = .21	SD = .14

Table F-2
Time to Identify Events by Condition (seconds)

Caps Off	Caps On	NVG Sim A	NVG Sim B
M = 54.3	M = 107.8	M = 35.8	M = 63.4
SD = 14.7	SD = 76.3	SD = 14.8	SD = 13.1

Appendix G

Means and Standard Deviations for Task Difficulty Ratings

Table G-1
Task Difficulty Ratings by Condition (collapsed over task category)

Caps Off	Caps On	NVG Sim A	NVG Sim B	Real World
M = 1.55	M = 1.99	M = 1.19	M = 1.21	M = 1.38
SD = .39	SD = .44	M = .30	SD = .19	SD = .43

Note. 1 = Could perform easily; 2 = Could perform with difficulty; 3 = Could perform with great difficulty.

Table G-2
Task Difficulty Ratings for Movement by Condition

Caps Off	Caps On	NVG Sim A	NVG Sim B	Real World
M = 1.54	M = 2.27	M = 1.29	M = 1.13	M = 1.42
SD = .51	SD = .58	M = .45	SD = .25	SD = .43

Note. 1 = Could perform easily; 2 = Could perform with difficulty; 3 = Could perform with great difficulty.

Table G-3
Task Difficulty Ratings for Visual Detection/Identification by Condition

Caps Off	Caps On	NVG Sim A	NVG Sim B	Real World
M = 1.54	M = 1.99	M = 1.12	M = 1.10	M = 1.50
SD = .54	SD = .60	M = .32	SD = .19	SD = .43

Note. 1 = Could perform easily; 2 = Could perform with difficulty; 3 = Could perform with great difficulty.

Table G-4
Task Difficulty Ratings for Target Acquisition by Condition

Caps Off	Caps On	NVG Sim A	NVG Sim B	Real World
M = 1.71	M = 1.82	M = 1.32	M = 1.50	M = 1.32
SD = .54	SD = .61	M = .46	SD = .48	SD = .42

Note. 1 = Could perform easily; 2 = Could perform with difficulty; 3 = Could perform with great difficulty.

Table G-5
Task Difficulty Ratings for Maintaining Situation al Awareness by Condition

Caps Off	Caps On	NVG Sim A	NVG Sim B	Real World
M = 1.58	M = 2.27	M = 1.21	M = 1.29	M = 1.38
SD = .60	SD = .64	M = .36	SD = .36	SD = .43

Note. 1 = Could perform easily; 2 = Could perform with difficulty; 3 = Could perform with great difficulty.